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Depth and Geoacoustic Parameter Measurement in Littoral Regions Using the UQN-4A Sonar Sounding Set

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13. ABSTRACT (Maximum 200 words) The data in this report demonstrates that SIMAS (Sonar In situ Mode Assessment System) can obtain current in situ bathymetric and geoacoustic information from the AN/UQN-4A Sonar Sounding Set (depth sounder) in littoral regions where vessels equipped with SIMAS systems will operate. Acoustic time series and digital depth output data were collected from the depth sounder for recording and transmission to the SIMAS system on-board the USS Curtis Wilbur (DDG-54). It was demonstrated that the digital depth output of the depth sounder could be acquired with little effort at a 30-second time interval instead of the present 5-minute time interval through the present data link. In addition, if the present depth sounder is modified to inhibit the writing to chart paper, then the sonar transmission pulse rate (ping rate) could be increased to provide shorter time intervals between depth samples to less than 3 seconds. This would allow depth soundings at distance intervals of approximately 100 ft at a ship speed of advance of 20 knots. The data clearly demonstrated the presence of geoacoustic information in the depth sounder acoustic return from the stratigraphy below the ship, but the limited bandwidth makes the extraction of this information complicated. Extraction of the geoacoustic information from these limited-bandwidth traces would require successive regression analyses to separate the time horizons and amplitudes of the reflections from each layer in the stratigraphic cross-section below the ship. This is computationally inefficient and can be easily remedied by using spread spectrum techniques. Spread spectrum signal generation and processing would require altering the present AN/UQN-4A by changing its signal processing circuits or sharing the present transducer with an additional transmitter, receiver, and signal processing hardware.				
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1.0 BACKGROUND

This task was conducted under PMO411ASW (SIMAS), Task Number USW-94-38A08.R1, at NRL, Stennis Space Center, MS, 39529-5004. The Principle Investigator was Mr. Raymond W. Fidler (NRL Code 7173) and the data analyses were conducted by the PI with contractor support from Mr. Robert Broome (PSI).

The best possible sonar performance prediction products from the SIMAS system require accurate bathymetric data. The most accurate bathymetry available aboard each SIMAS equipped vessel is from fathometer measurements. There is a scarcity of reliable bathymetry and bottom reflectivity data in the Littoral Regions around countries where SIMAS systems might be called upon to provide sonar predictions. Both problems can be overcome by acquiring in-situ measurements of the velocity structure, depth and bottom characteristics of the area during the time of the deployment. The resulting data can be archived in the fleet during deployments in Littoral Regions of interest. This will build a current acoustic database and allow for determination of spatial and seasonal variations.

Effective utilization of the AN/UQN-4A at its maximum output rate or modification of the current operation to increase the current rate can be very useful in providing finer resolution of the geoacoustic parameters, while at the same time preventing accidental damage to the tactical towed array. This improvement could be accomplished by mode control and signal processing improvements.

Proper use of SIMAS in littoral waters requires accurate knowledge of the water depth and bottom acoustic characteristics in the immediate operating region, in addition to the water column sound velocity profile. It is almost impossible to obtain accurate, high resolution sea floor information from current databases. When the sea floor information is present in these databases, the data are of low-resolution that does not adequately account for the spatial and temporal variation of bottom acoustic characteristics in the littoral environment. The bottom characteristics are only likely to change due to storms and longer term deposition changes that are sensitive to how near the region is to the surf zone and rivers.

The current database that SIMAS uses contains data largely derived by extending the database information actually measured and/or predicted from deep water or "basin" models. This is further complicated by the fact that in many areas of the world littoral bathymetric data were not acquired with adequate navigation information and have been forced to fit or match the topography of the land. The depth contours of bathymetry maps in littoral regions near the shore are very coarse and lead to large errors in depth prediction at any given location. The horizontal cell resolution of the littoral databases is on the order of 5 miles by 5 miles which masks a great deal of information on the true structure of the bathymetry. The depth assigned to each position in a 5 minute by 5 minute cell (i.e., approximately 5 X 5 nautical mile area) is the average depth in the large cell.

The AN/UQN-4A can be used to measure the depth and bottom characteristics directly under the ship with a much finer resolution than the DBDB5 Charts or bathymetric data bases. Transiting the area will provide a track in the area. Multiple transits can be used to form an area of observations which could be used to check or build a region of specific bathymetric, velocity profile, and bottom characteristics database for SIMAS.

Information from the following two programs were factored into this task effort. First, the Marine Corps amphibious warfare program in acoustic/seismic surveillance from 1973 through 1982 at the Naval Coastal Systems Center (now NCSS) in Panama City, FL., conducted research into seismic and acoustic propagation (with mode conversions between) from several miles inland to several hundred feet of water. Second, the Marine Geophysical Survey and Vertical Seismic Profile

problems in the Persian Gulf area (in the tidal zones) and land mass of Saudi Arabia, researched from 1982 through 1985.

Additional information of particular interest were reviewed to direct application to the task effort. The Naval Research Laboratory at Stennis has worked with NCSS on the mine warfare and geoacoustic parameters measurements. Some efforts at NRL Stennis, NAVOCEANO, ARL University of Texas, and other places are investigating the littoral region problems which have limited application to SIMAS but what is applicable is being incorporated into this task to economize.

The effort at ARL University of Texas for the Defense Mapping Agency includes developing replacement equipment for the AN/UQN-4A which is necessary to improve the measurement of depth for bathymetric maps generated by that agency. This is especially true of littoral regions. DMA is aware of PMO-411G's efforts and wants to coordinate with Commander Steve Schrobo (and R. W. Fidler) in generating the requirements and specifications for developing DMA's equipment to make the kind of system which will gather good depth data in support of PMO-411. ARL has a portable system which is a prototype system for temporarily replacing the present AN/UQN-4A on-board the ships it is deployed on.

2.0 OBJECTIVE

The experiment described in this report is a test of an interface between the AN/UQN-4 Sonar Sounding Set and the AN/UYQ-25B(V) (SIMAS II Prototype). The primary objective of the experiment is to compare digital depth soundings acquired with this interface, with the DBDB5 bathymetry data base used by SIMAS II. This database has a five minute latitude and longitude resolution, which is much coarser than the resolution of the fathometer. The higher resolution will be required for acoustic performance prediction in highly variable Littoral Regions.

The secondary objective of this experiment is to collect data suitable for extraction of sea floor geoacoustic parameters. Geoacoustic parameters such as sediment layer thickness, sediment density, and sound speed are presently determined only from historical data, where this is available. The ability to measure the parameters in-situ using standard ship's equipment will enable SIMAS II to more effectively support proficient utilization of the ASW combat system in highly variable Littoral Regions.

3.0 EXPERIMENT DESIGN

The data collection effort was performed on the USS CURTIS WILBUR (DDG-54) during August 1994. Specialized recording equipment was connected to the ship's AN/UQN-4A. Analog acoustic echo trace data were digitized and recorded along with the AN/UQN-4 estimated depth in several different littoral and near littoral areas of the US west coast, on a not-to-interfere basis, during a transit from San Diego to San Francisco.

The following goals were established, in order to meet the objectives of the experiment:

1. Demonstrated the ability to acquire both analog and digital data from the AN/UQN-4A Sonar Sounding Set.
2. Process the digital data and transfer it in real-time to the AN/UYQ-25B (V) (SIMAS).
3. Store the digital and analog data in a database for later processing to compare the digital depth information with the DBDB5 database and with the acoustic data.

4. Analyze the data to determine the data characteristics important to SIMAS II.

The data were collected using COTS hardware assembled into the high resolution data recording system shown in Figure 1. A Gateway P60 ISA computer was used as the data logging device. Two kinds of depth data from the AN/UQN-4A Sonar Sounding Set were acquired by the computer. The acoustic data were acquired from the headphone plug on the AN/UQN-4A unit. In addition, digital data were acquired from the AN/UQN-4A display system. These data, displayed by the AN/UQN-4A using nixie display tubes, were recorded by the computer. All data were written to the internal two gigabyte hard disk and later backed up to 4mm digital tape.

The acoustic signals were digitized using an Commercial-Off-The-Shelf (COTS) ISA compatible digitizer (a MediaVision JAZZ16 sound card). This digitizer was used to interface the computer to the AN/UQN-4A analog acoustic trace signal. This digitizer is capable of processing two channels of data at 16 bit resolution (-32768 to +32767). The digitizer has software selectable sample rates of: 44.1 KHz, 22.05 KHz, and 11.025 KHz. A custom ISA card was designed to interface the Gateway computer to the AN/UQN-4A Nixie Tube output for digital depth reading from the depth sounder. The AN/UQN-4A digital depth data was transferred to SIMAS with the FTP protocol through an ethernet card installed in the Gateway computer. During this experiment, the acoustic data were digitized by the computer and recorded on an internal hard disk for later archiving on 4 mm DAT tape. No acoustic data or analysis results were transferred to SIMAS during this experiment.

The analog data collection equipment was designed to trigger on the TVG (Time Varying Gain) pulse generated by the AN/UQN-4A Sonar Sounding Set. This TVG pulse lasts as long as the transmission. Inadvertently, the trailing edge of the TVG pulse was used as the trigger, resulting in some problems in measuring the total travel time of the leading edge of the pulse. These problems, which affected the analog data only, had to be compensated for. During processing each recorded trace was lengthened by the total time of the pulse in order to correctly measure the total travel time. This start time signal selection also had the unintended effect of generating false echo return traces. Other pieces of sonar equipment generated a TVG pulse to prevent overloading the AN/UQN-4A. Each time such a TVG pulse occurred, an invalid data record was generated. Fortunately, such records are easily identified since the data recorded in them is all zeroes.

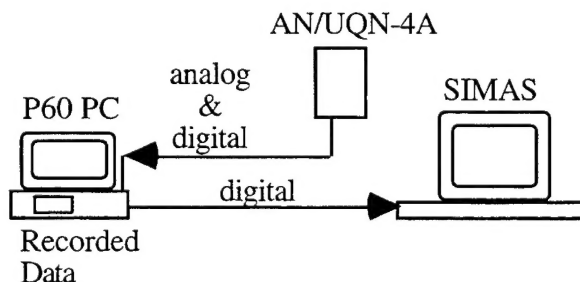


Figure 1. Field Test System and Functional Connections.

4.0 DATA COLLECTION

All the data were collected on-board the USS CURTIS WILBUR (DDG-54) during a transit from San Diego to San Francisco. The data were collected during a three day period from 22 August 1994 to 24 August 1994. Two kinds of data sets were acquired: long duration tracks where the ship covered as much distance as possible, and shorter tracks where a single bottom type was extensively sampled. Eight data sets were collected for a total of 4387 depth measurements and 20

hours 22 minutes of recorded data. These data sets are summarized in Table 1. The locations where the data sets were collected are shown in Figure 2.

The experiment recorded every ping of the AN/UQN-4A system during a series of "runs". The AN/UQN-4A was set to produce pings every 30 seconds. All pings during a run were recorded. The emphasis during this experiment was to acquire the data and demonstrate the ability to transfer the data to SIMAS. Because of this, only necessary supporting environmental data (time and dead-reckoning position) were recorded.

TABLE 1
UQN-4 Data Collection Exercise.
All data collected on 8/23/94 and 8/24/94

Run #	filename	start latitude	start longitude	end latitude	end longitude	crse	speed over track	start time	end time	duration
1	tuesmorn	33° 00'	-118° 00'	33° 12'	-118° 03'	300	7	13:56:12	15:01:46	1' 04"
2	tuesmid	33° 03'	-118° 03'	33° 00'	-118° 00'	300	7	15:14:10	15:36:32	0' 22"
3	tuesnoon	34° 51'	-121° 35'	34° 25'	-121° 14'	155	32	19:15:44	20:15:22	1' 00"
4	2023Z	34° 17'	-121° 09'	34° 56'	-121° 35'	335	42	20:29:15	21:33:48	1' 04"
5	2137Z	35° 05'	-121° 36'	35° 06'	-121° 30'	355	0.1	21:46:14	23:16:06	1' 30"
6	2321Z	35° 07'	-121° 35'	35° 30'	-121° 51'	335	8.5	23:25:00	02:33:06	3' 08"
7	0237Z	35° 36'	-121° 53'	37° 18'	-122° 30'	335	9.7	02:43:54	13:46:17	11' 02"
8	wedsmorn	37° 22'	-122° 34'	37° 30'	-122° 34'	000	4.0	13:55:58	15:03:55	1' 08"
9	sanfran	37° 48'	-122° 24'	37° 48'	-122° 24'	000	0.0	15:07:28	15:21:04	0' 04"

Run #	filename	Sample Rate	# of Pings	lway sec	# bytes/ ping	Start Depth (fthms) Corrected	Start Depth (fthms) DBDB5
1	tuesmorn	11025	259	1.6	35324		
2	tuesmid	11025	20	1.1	25164		
3	tuesnoon	22050	423	1.6	70604	548	558
4	2023Z	44100	490	3.0	264644	406	1090
5	2137Z	22050	114	16.0	705644	612	550
6	2321Z	22050	344	1.6	70604	452	550
7	0237Z	44100	1307	3.0	264644	562	566
8	wedsmorn	22050	621	1.6	70604	36	8
9	sanfran	44100	809	0.395	35324		

**AN/UQN-4 DATA COLLECTION RUNS 1-9
AUG. 23-24 1994**

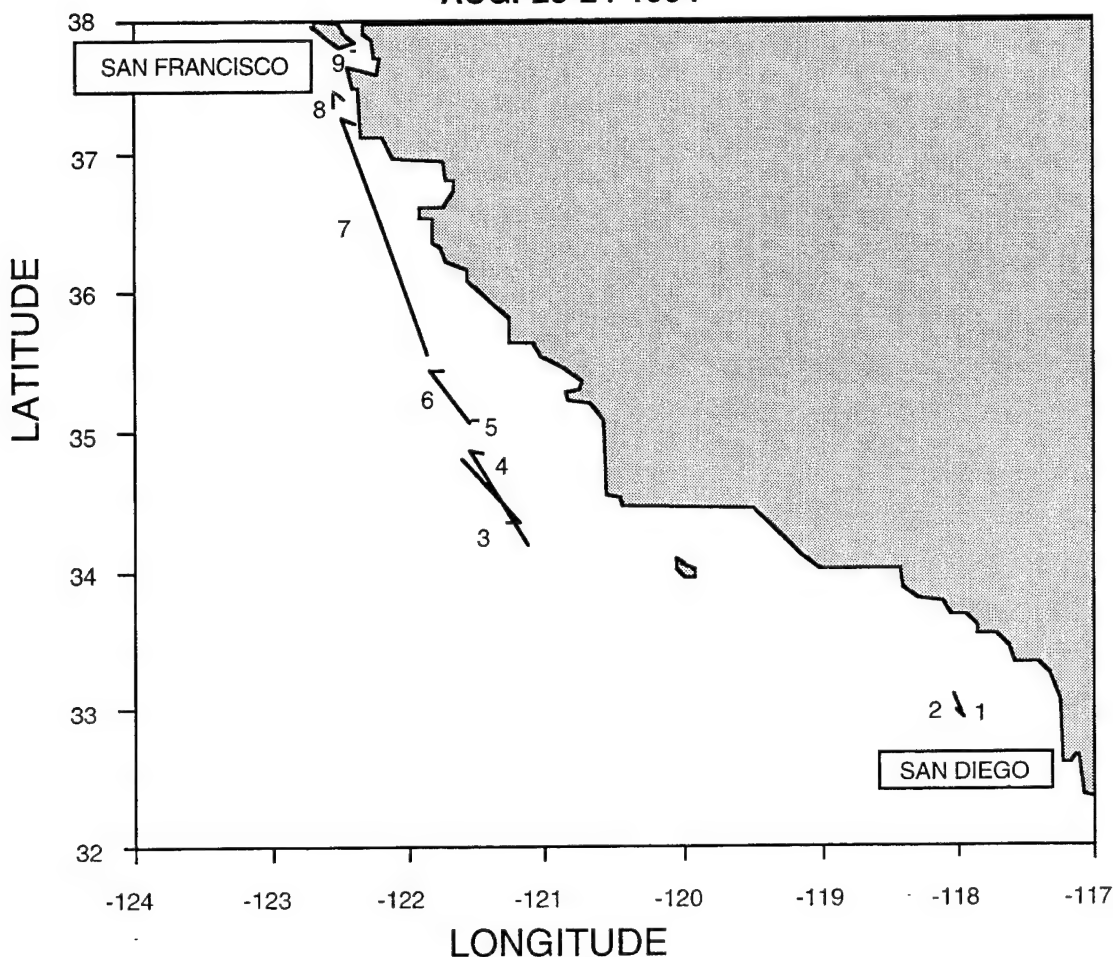


Figure 2. Locations of Data Sets.

The record length of each ping is constant for a given run. The record length for each run is determined by the user at the beginning of the run and is not changed during the run. The sample rate is also determined by the user at the beginning of each run. Generally, either 1.6 sec or 3.0 seconds of data were recorded, depending on the water depth. Runs 2, 5, and 9 were special cases. Run 2 was recorded for only 1.1 sec per ping, run 5 was recorded for 16 sec per ping, and run 9 (in San Francisco bay) was recorded for only 0.395 seconds per ping.

The recorded data consists of two kinds of files. For each ping of the Sonar Set, a fixed length binary file containing the acoustic signal from the AN/UQN-4A Sonar Set is recorded. The format of this file is the standard WAVE format as defined by Microsoft Corp. This WAVE format allows many commercial packages to read these data files without modifications. The details of this format are given in any text on programming under MS Windows. The data in these files consists of fixed length binary records containing 16 bit (two's-complement binary) data. Header information stored with the file contains the sample rate of the data, the number of channels (always 1), and the number of data points. All other information about the data is contained in a separate ASCII file.

The separate ASCII text file containing header information (shown in Figure 3), including the digital acoustic data from the AN/UQN-4A, is also recorded when the binary data file is recorded.

The binary and ASCII files are associated by their file names. The Position, Speed, and Heading represent these values at the beginning of each run, corrected using dead reckoning for each subsequent file. In general, the positions recorded in the header files were only considered accurate for the first ping file. Subsequent files must be corrected for set and drift. The times and UQN-4A Depth are accurate for all ping files. Figure 3 is a digital listing of the ASCII file with all its spelling errors. Var is meaningless but was included for possible use at another time.

```
Time Src: Internal
GMT Time (seconds since 1970): 777684381
GMT Time: Tue Aug 23 23:26:21 1994

Latitude: Dead Reconing: 35.204 Degrees Var: 0.010
Longitude: Dead Reconing: -121.633 Degrees Var: 0.010
Speed: Dead Reconing: 17.200 Knotts Var: 0.100
Heading: Dead Reconing: 335.000 Degrees Var: 0.100
Depth: Not Implemented: -999.000 Var: 9999.000
Depth: UQN4: 460.000 Fathoms Var: 27.600
Depth(acoustic): Not Implemented: 9999.000 Meters Var: 9999.000
Sound Speed: 1500.000000
Raw Acoustic Ping: D:\DATA\2321Z\RAW0002.wav

Filtered Acoustic Ping: D:\DATA\2321Z\PRC0002.wav
```

Figure 3. Example Contents of the ASCII Header File for all Pings.

5.0 DATA ANALYSES

As planned, data were collected from two different AN/UQN-4A sources: the digital display readout and the acoustic signal from the transducer. The digital data is intended for use by SIMAS as an improvement to the existing bathymetry database. An example of how the digital AN/UQN-4A data compares to DBDB5 bathymetry is shown in Figures 4 through 9.

5.1 DIGITAL DATA

Data were not processed from runs 1 and 2 because during these runs the ship performed a large number of undocumented maneuvers. Accurate comparisons with the DBDB5 bathymetry database are not possible because of the uncertainty in position. Run 9 was actually recorded while the ship was tied up at the dock in San Francisco. No comparisons with the DBDB5 bathymetry database are possible there.

The AN/UQN-4A Sonar Set reports data relative to the keel of the ship. The data in the ASCII header files have been corrected by this keel depth, 31.8 feet, such that all data are now relative to the sea surface.

The data in Figures 4 through 9 compare the nixie tube data from the AN/UQN-4A with the DBDB5 database used in SIMAS. The thick lines are the DBDB5 depths and the thin lines are the UQN-4 depth estimate. In order to make this comparison, the initial position, course, and speed of the ship was obtained from the header file of the first ping. The initial position of the subsequent run was obtained from the initial ping file of that run. Both positions were plotted, and the reported course and speed were used to estimate the position of the ship during the run. The course and speed of the data ship were assumed to be constant during each run. The position of the subsequent run was used if necessary to correct the course vector of the ship to make sure that

small errors due to ocean currents and wind effects on the ship did not result in impossible positions or speeds.

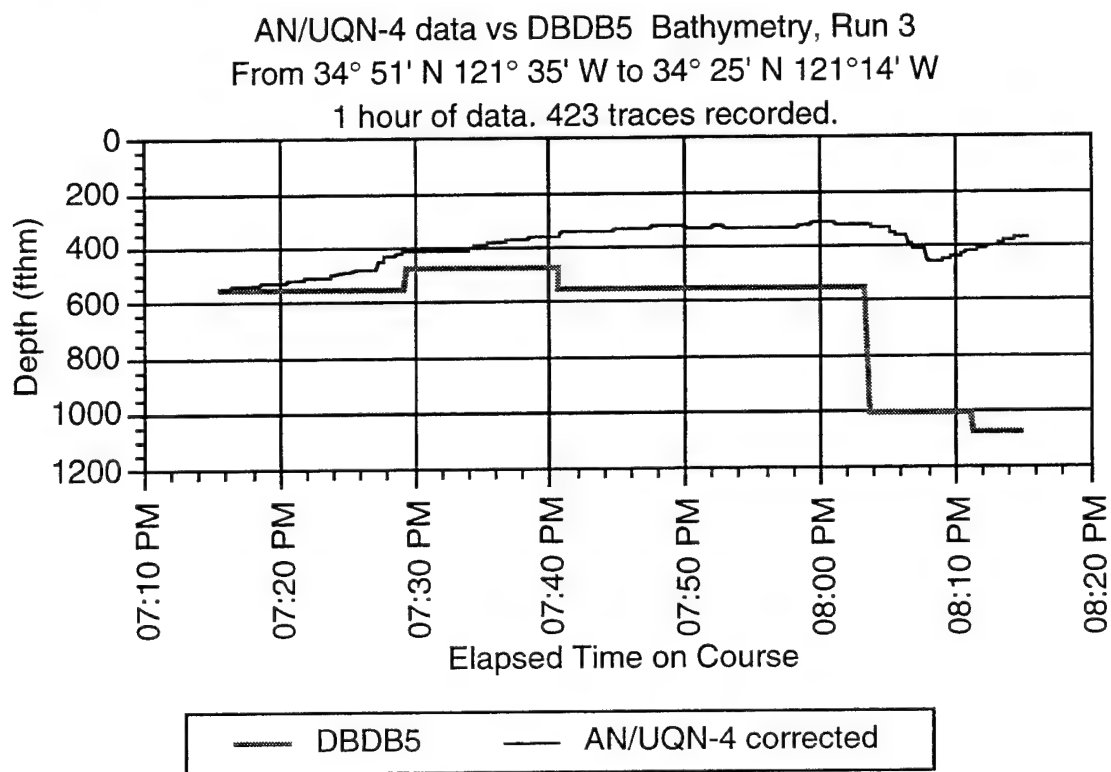


Figure 4. Comparison for Run 3.

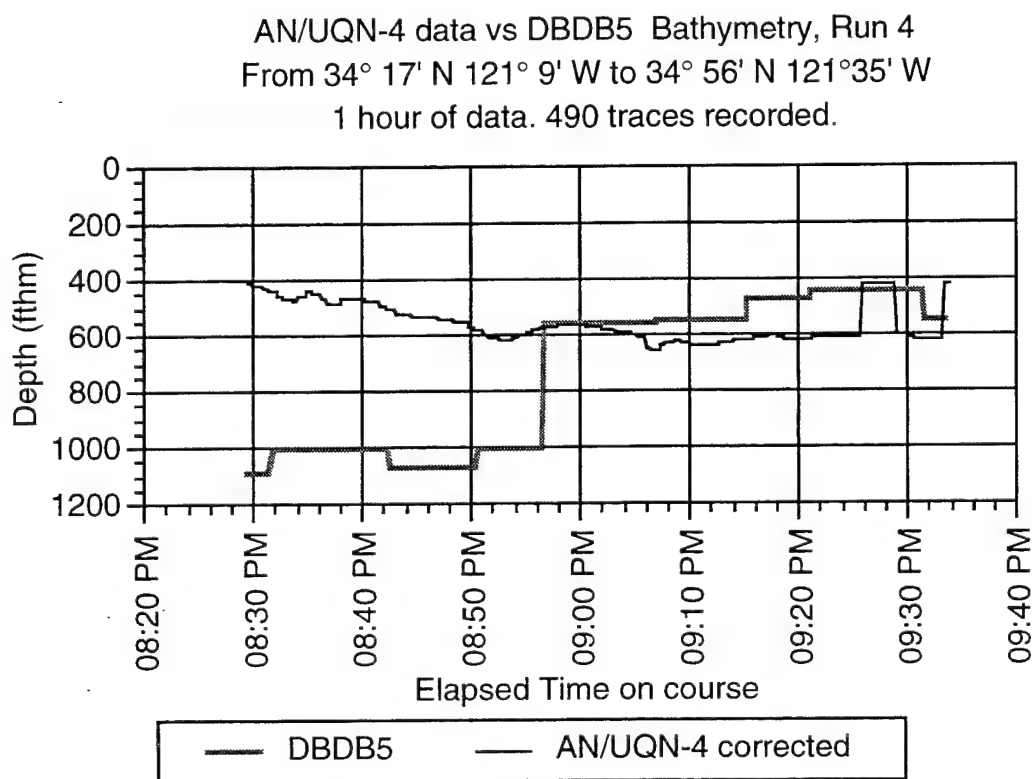


Figure 5. Comparison for Run 4.

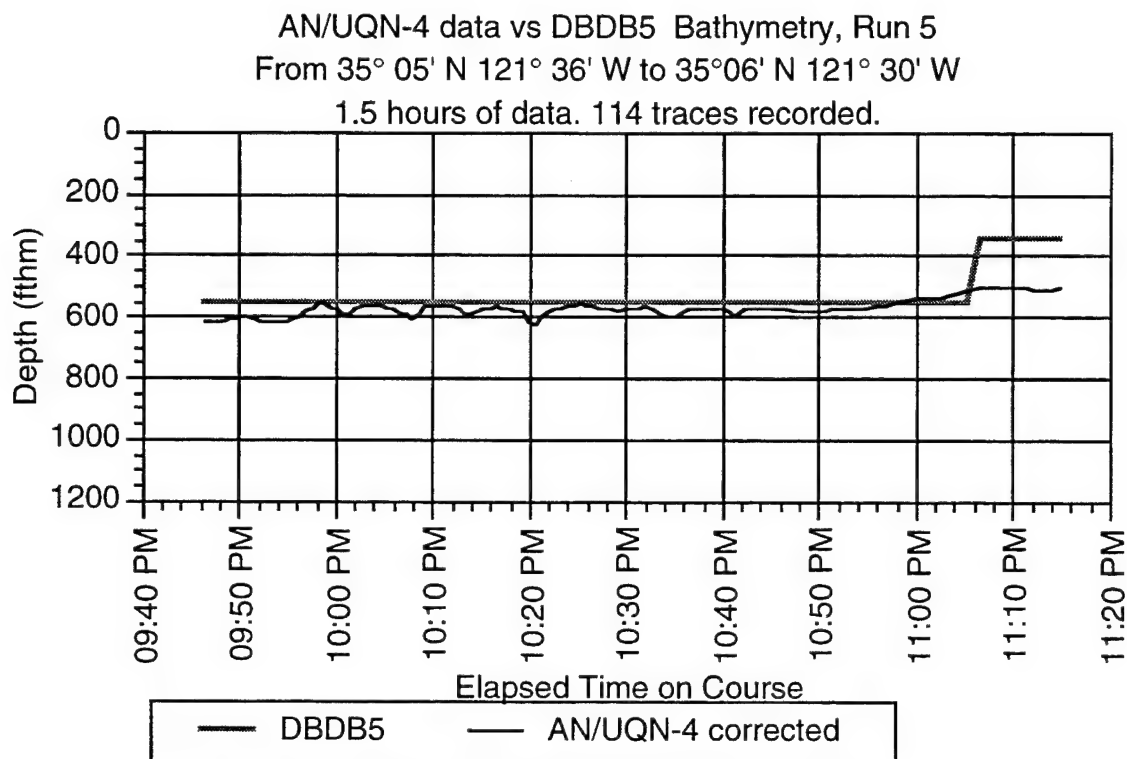


Figure 6. Comparison for Run 5.

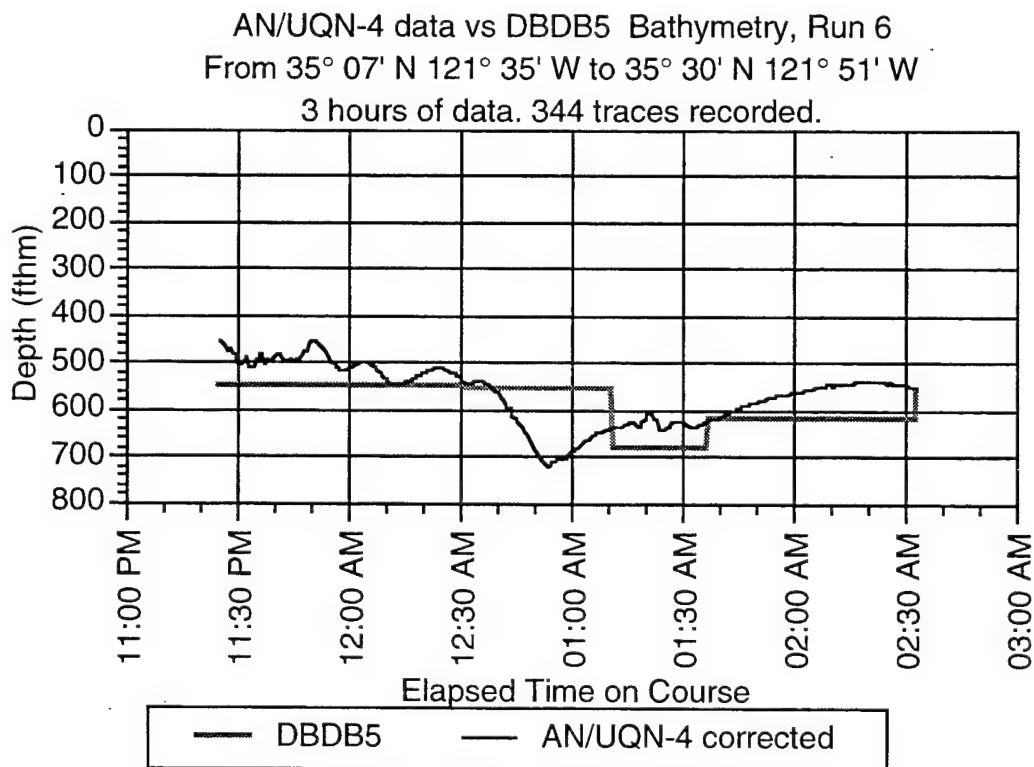
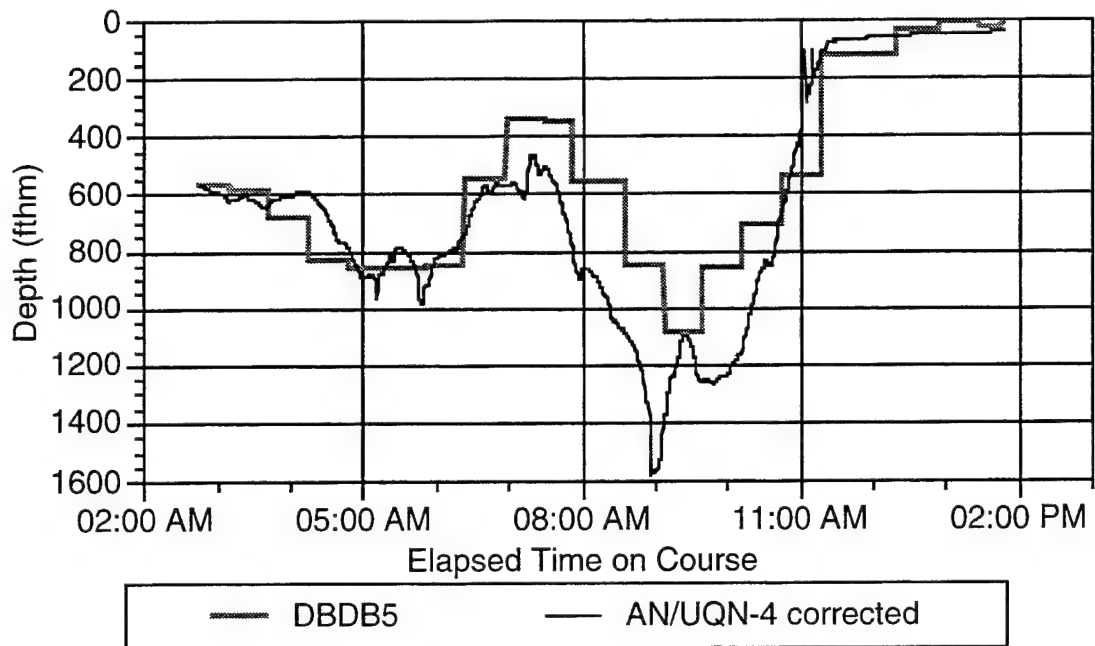
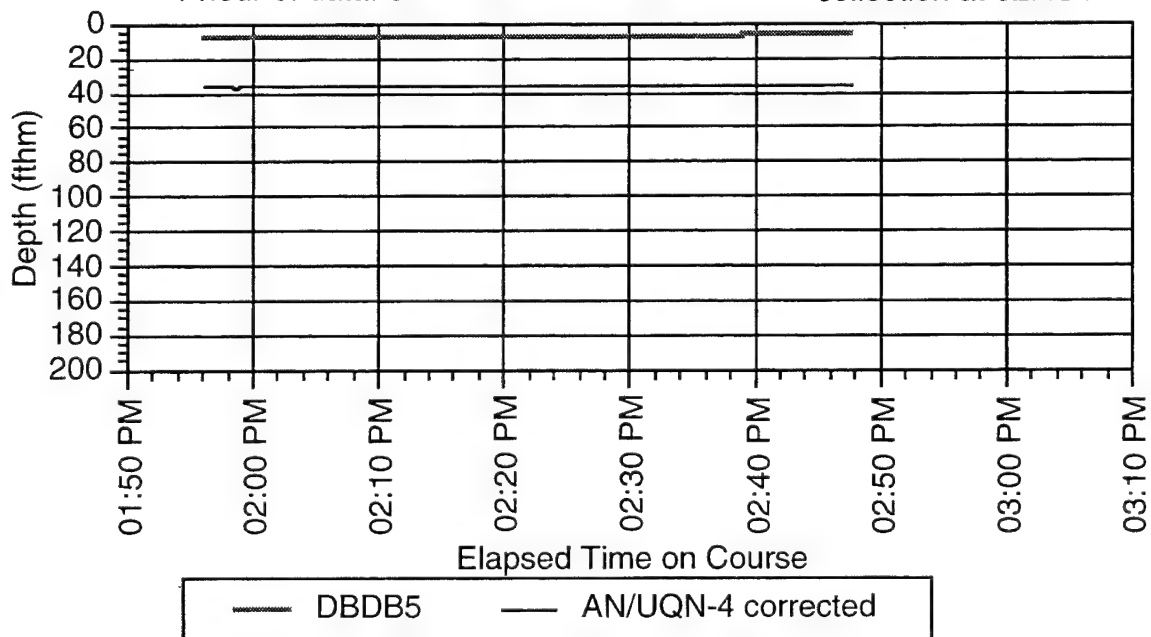


Figure 7. Comparison for Run 6.

AN/UQN-4 data vs DBDB5 Bathymetry, Run 7
 From 35° 36' N 121° 53' W to 37° 18' N 122° 30' W
 11 hours of data. 1307 traces recorded.



AN/UQN-4 data vs DBDB5 Bathymetry, Run 8 Suspected Equipment
 From 37° 22' N 122° 34' W to 37° 30' N 122° 33' W Failure terminated data
 1 hour of data. 621 traces recorded. collection at 02:48 PM



Cumulative Probability Function for Depth Errors
 Depth Differences are $|AN/UQN4 \text{ minus } DBDB5|$ for Runs 3,4,5,6,7,8
 A total of 3294 AN/UQN4 points are compared to DBDB5 data

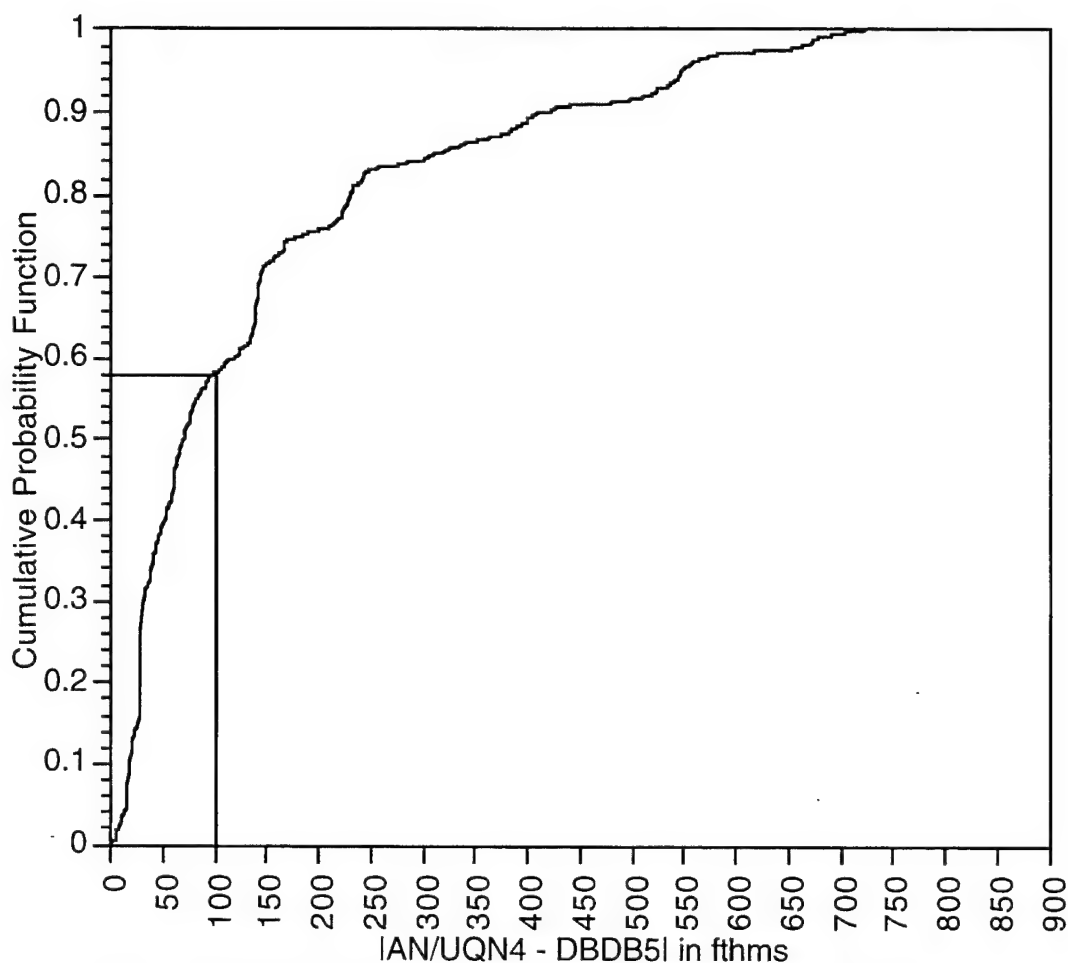


Figure 10. Cumulative Probability Distribution of Runs 3,4,5,6,7,8.

The difference between the UQN-4 depth estimate and the DBDB5 database was calculated. The absolute value of the difference was then used in a computed data file for running the statistical analyses of the information. The density function of the errors was analyzed for each run and for the composite set of all data to determine the reliability of the data comparison. After careful analyses were conducted, the result shown in Figure 10 was deemed to be the best possible interpretation of the UQN-4 vice the DBDB5 data.

The cumulative probability distribution shown in Figure 10 provides a summary of the likelihood that the DBDB5 database will be in error by some given amount. For instance, Figure 10 shows that 42% of the measurements taken during this experiment were more than 100 fathoms different from the DBDB5 database for that position.

All the acoustic data collected during this experiment are uncalibrated, so all the data presented here are normalized in amplitude by dividing the time series data by the largest possible integer value (32,768). Time series plots and spectral analyses of the acoustic data traces was conducted to verify the purity of the recorded data and possible crosstalk and/or interference (contamination) in

the data. The next two sections present examples of the spectral analyses information and then the time series analyses.

5.2 ANALOG DATA - SPECTRAL ANALYSIS

Figure 11 shows a Fourier Transform of the bottom return only in a sample ping file from Run 6 (file RAW0002.WAV). The data were transformed using a 8192 point transform, and only the last 8,192 points in the file were used. As one can see from the transform, there are two signals in the data. The first signal at 4753 Hz, spectral peak next to the 4800 vertical marker line drawn in the figure for reference, is the heterodyned acoustic return from the bottom. There is a second signal at 6273 Hz which could be the signal the AN/UQN-4A Sonar Set mixes with the nominal 12 KHz acoustic return to produce a signal suitable for the headphone output. But, according to the AN/UQN-4A specifications, this signal should be at 7200 Hz. The fact that it is not could imply that the AN/UQN-4A used in this experiment was not in fact producing a 12 KHz acoustic signal. This would lead to the actual acoustic signal produced by the transducer as being a 11026 Hz signal which can not be determined in the figure.

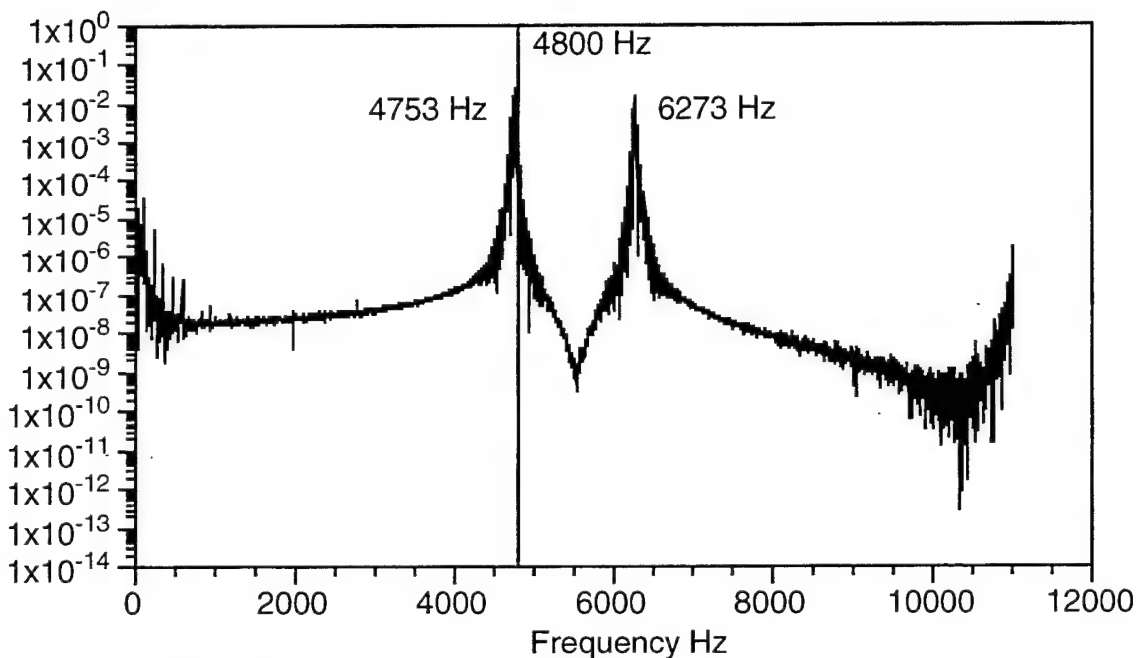


Figure 11. Single Ping of AN/UQN-4A Data Sampled at 22050 Hz.

Figure 12 shows a Fourier Transform of the bottom return only in a sample ping file from Run 7 (file RAW0004.WAV). The data were transformed using a 16384 point transform, and only the last 16384 points in the file were used. There are two vertical reference lines drawn in the power spectra plots; one is at 4800 Hz and one is at 1200 Hz. As one can see from the transform, there are two or more signals in the data. The first signal at 4753 Hz is assumed to be the acoustic return from the bottom. The other signals at 6987 and 9300 Hz (spectral peaks) are unknown.

In the following few paragraphs I will attempt to clarify the filtering present in the AN/UQN-4A upstream of the headphone jack. This discussion is intended for anyone who wishes to search out the details from the AN/UQN-4A manual or they can just follow the logic.

This discussion starts with reference to the 1A4A1 receiver schematic, on page 49 of the UQN-4 manual. First note that the receiver has three outputs, on pins 18, 68, and 46 of P1 (right side of the schematic). Pin 18 goes to the headphone jack (through amplifier 1A4A2) when the UQN-4 is

set to 600 feet. For other ranges, pin 68 goes to the headphone jack for short pulses, and pin 46 goes to the headphone jack for long pulses. This can trace out by referring to the top, center part of page 31 of the manual.

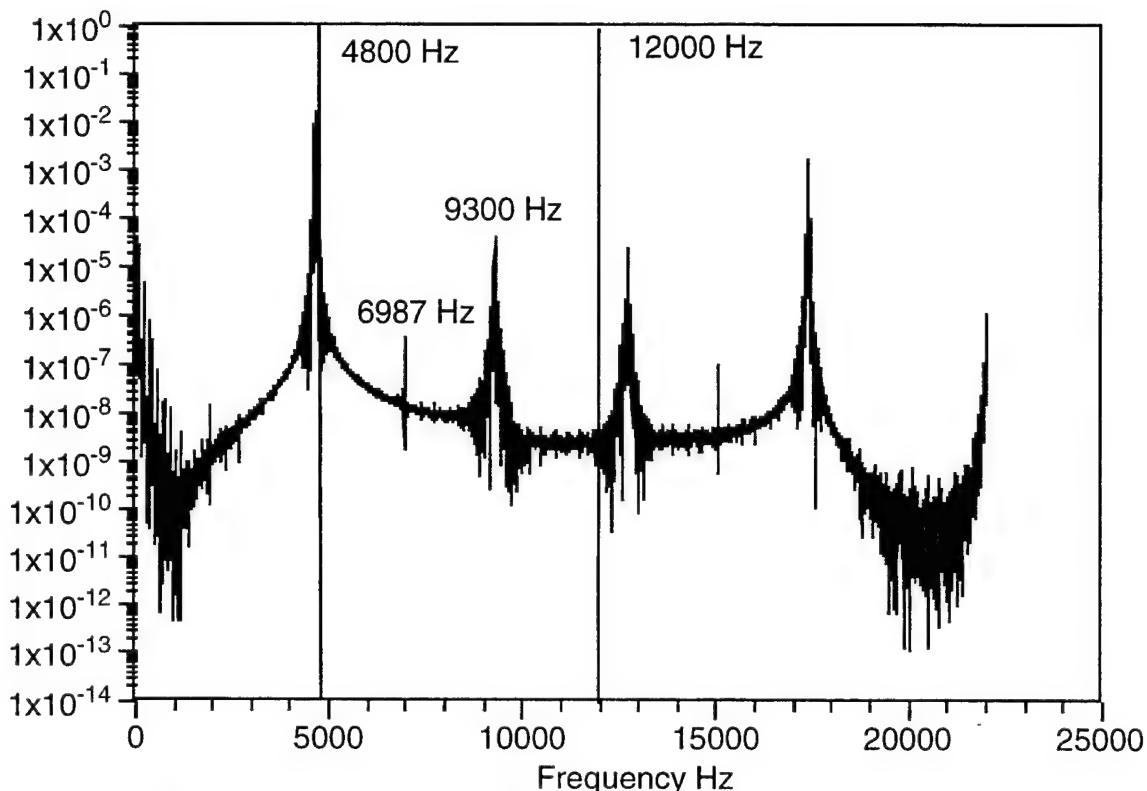


Figure 12. Single Ping of AN/UQN-4A Data Sampled at 44100 Hz.

Going back to page 49, note that the 12 KHz signal goes through N-FL-1 on the left of the schematic. N-FL-1 is a bandpass filter centered at 12 KHz, with a bandwidth of 4.0 KHz (3 dB down points are 10 KHz and 14 KHz). This signal is amplified and goes out to P1 pin 18; This is the signal out of the headphone jack on the 600 foot range.

For other ranges, the 12 KHz is beat against 7.2 KHz in I-MXR-1 (right of center) and is filtered by N-FL-2. NFL-2 is centered at 4.8 KHz, with an 800 Hz bandpass at the 3 dB down points. (I assume the manual means 400 Hz either side of 4.8 KHz, but this is not specifically stated. I am assuming that 3 dB down points are 4400 and 5200 Hz).

For long pulse only, N-FL-3 provides additional filtering. The bandpass of N-FL-3 is 80 Hz either side of the 4.8 KHz center frequency. N-FL-3 is not used in the short pulse mode of this data.

There is no filtering downstream of 1A4A1. (This can be seen in the headphone amplifier schematic, second circuit from the top of page 51).

Since the spectrum shows a peak near 4800 Hz, it is assumed to be the heterodyned signal. This means that the AN/UQN-4A is not in the 600 feet mode but is in the 600 fathoms mode. The Equipment Specifications chart on page 11 states that the intermediate frequency is used in the fathoms mode. Therefore, the headphone signal was being filtered by at least 1-FL-2, which has a bandpass of 400 Hz (each side of 4800 Hz). You have 5825 Hz of guard band between the 5200 Hz 3 dB point and the 11,025 Hz Nyquist frequency. This is 14.5625 times the 400 Hz

half-bandwidth of the filter. This leads to the conclusion that the AN/UQN-4A has a built-in anti-alias filter.

However, filtering inside the AN/UQN-4A will not help against signals injected into the cabling downstream from the AN/UQN-4 (between the depth sounder and the analog-to-digital converter). The cables run half way across the Sonar Control room to get from the AN/UQN-4A to the PC computer.

One hypothesis is that there is crosstalk. The 22,050 Hz sampling signal may also be getting into the audio somehow. Facts which support this hypothesis are:

- a) AN/UQN-4A filters have considerable signal rejection at the 11,025 Nyquist frequency,
- b) and the 6273 line is very close to what you would expect from aliasing that signal.

An alternative hypothesis is that the AN/UQN-4 was transmitting at 11,026 Hz, and the local oscillator was tuned to 6273 Hz, thereby producing a 4753 Hz IF signal. However it should be noted that the 12,000 KHz transmit signal is not derived through a heterodyning process. We have to ask, therefore, how it would be possible to have these two signals off by the exact amounts required by the hypothesis.

Referring to page 60 of the manual, it can be seen that some graphs (left side of page) show how the transmit signal is derived from 72 KHz and 24 KHz waveforms. The circuitry which accomplishes this includes flip-flops 1-FF-4, 1-FF-5, 1-FF-6, and 1-FF-7, in the lower right quadrant of page 61. If you trace the 72 and 24 KHz signals back to their source, you end up in 1A4A3, on page 53. The 72 KHz waveform comes from pins 64 and 58 (slightly left of center, and the 24 KHz signal comes from pin 10. Note that the 24 KHz signal is derived from the 72 KHz signal through a divide-by-three counter (1-FF-2 and 1-FF-3, lower left), and the common source is the 144 KHz oscillator, O-OSC-1, at left center.

Also, the 7.2 KHz beat frequency signal used in the receiver comes from pin 37 of the same card (center of drawing vertically, slightly left of center horizontally). The 7.2 KHz is derived from the same 72 KHz signal through a divide by ten counter 1-CTR-1 (left center). Since the amount of the hypothetical frequency shift will not support an assertion that a counter is scaling incorrectly, it can only be hypothesized that the 144 KHz oscillator is running slow. If it is asserted (as the hypothesis requires) that the oscillator is running slow enough to produce a 6273 Hz beat frequency oscillator (BFO) instead of a 7200 Hz tone, then the 144 KHz master oscillator must be running at 125,460 Hz. This would reduce the transmit frequency proportionately from 12,000 Hz to 10,455 Hz. However, this hypothesis requires a transmit frequency of 11,026 Hz (in order to produce a 4753 Hz tone when beat against a 6273 Hz BFO). Since the transmit frequency cannot be equal to 10,455 Hz and 11,026 Hz at the same time, the latter hypothesis must be rejected.

Having eliminated alternate explanations, we are forced to conclude that crosstalk within the PC or interconnection cable is responsible for the observed 6273 Hz spectral peak. This crosstalk most likely involves feed-through of the 22,050 Hz sampling signal. The problem with this system was that the procurement and hardware development was hastily done over a period of less than 5 weeks with only a weekend to "marry up" our system to the systems on the ship. Therefore, as usual, close attention must be paid to shielding and dressing of the input wiring during the design and construction of any production hardware.

5.3 ANALOG DATA - TIME DOMAIN ANALYSIS

The discrete time series of the analog acoustic data, from the depth sounder, were plotted in many normalized amplitude versus round trip time (or depth) plots for analyses. Some plots were compressed in depth to show entire traces on single pages to observe gross behavior of trace data. When finer detailed information of traces was desired, the depth scale was expanded (less compression) and plotted for only the depth portion of interest that was determined from the highly compressed plots of the whole trace. The expanded time/depth series data provided analyses of the transmitted frequency, bottom return time, return echo complexity. These properties, for a few of the acoustic traces, were analyzed in detail and some of the plots will now be presented to partially demonstrate the nature of the data analyses that led to the conclusions and recommendations at the end of this treatise.

Six traces are shown in Figure 13. The amplitude of each time sample was squared (to generate a power series) and then the power trace was envelope detected for each compressed envelope plot in the figure. These envelope traces indicate what the depth sounder used to determine the bottom return depth. The first arrival time is easily seen and can be detected by setting a threshold to detect the time of the abrupt increase in amplitude on the front part of the power envelope of the first echo return as can be seen for six consecutive traces in Figure 13. The six traces in Figure 13 demonstrate how the depth (return pulse echo) varies with the pulse arrival time changes for the first part of the data set labeled 2321Z.

In Figure 13, the return pulse length (echo) for each trace is approximately 291 millisecond which indicates penetration of about 700 feet into the bottom. An expanded view of the same six traces is shown in figure 14 where superposition of the multiple returns from the different seismic layers and their "peg-leg" multiples can be seen as complex amplitude variations of the echoes. The "peg-leg" multiples are from the seismic energy bouncing back and forth (up and down) within and between layers with a little energy returning each time the bouncing wave reflects downward since some is transmitted and some is reflected at each layer boundary. The effect is to add decreasing amounts of the original signal to the trace with a time delay proportional to the layer thickness and inversely proportional to the wavefront velocity. This is manifest in a periodic modulation of the time series amplitudes which can be seen in the traces. The first interference pattern time length is proportional to the two way travel time in the top layer and the ratio of the double layer thickness of the down and back path traveled to the wavefront velocity. The longer interference pattern is proportional to the next layer.

The complex amplitude patterns for the six traces show remarkable repetition between adjacent traces as should be expected for continuous bottom layering data. The time of first arrival is clearly obvious in the traces. The complex superposition of the different reflected signals with their different amplitudes is generally handled by deconvolution of "peg-legs" and then regression (sequential suppression) analyses of the succeeding returns in the echo. This requires considerable computational effort and often human interpretation and interdiction in the processing sequence. That processing methodology is beyond the scope of this report and will not be pursued further.

The first acoustic time trace from Figure 14 was expanded in Figure 15 to show the shortest interference pattern in the trace. This pattern is from the first layer of the bottom which is probably less than 1 ft. The trace appearance (amplitude modulation) appears to have a reflection coefficient (γ) of slightly less than 0.1. An estimate of 0.1 for the reflection coefficient at the surface of this layer would indicate a velocity in the layer of around 5800 ft/sec ($\gamma \approx [V_2 - V_1]/[V_2 + V_1]$) which corresponds to saturated silt or mud over a hard bottom layer below the thin surface layer.

The same trace was compressed to show the trace in Figure 16. The initial interference pattern indicates another layer below the surface layer of the bottom. This layer appears to be around 48 ft thick and have a higher velocity than the unconsolidated layer which also indicates that the second layer is probably consolidated and slightly faster than the first layer. These are interpretations based on experience of reading hundreds of Vertical Seismic Profiles over several years of seismic research.

Figures 17 and 18 are from another trace in Figure 14 and demonstrate the consistency of the interference patterns from the top two layers and possibly from the third layer but none of these estimates have been verified from borehole wells or assumed stratigraphic databases.

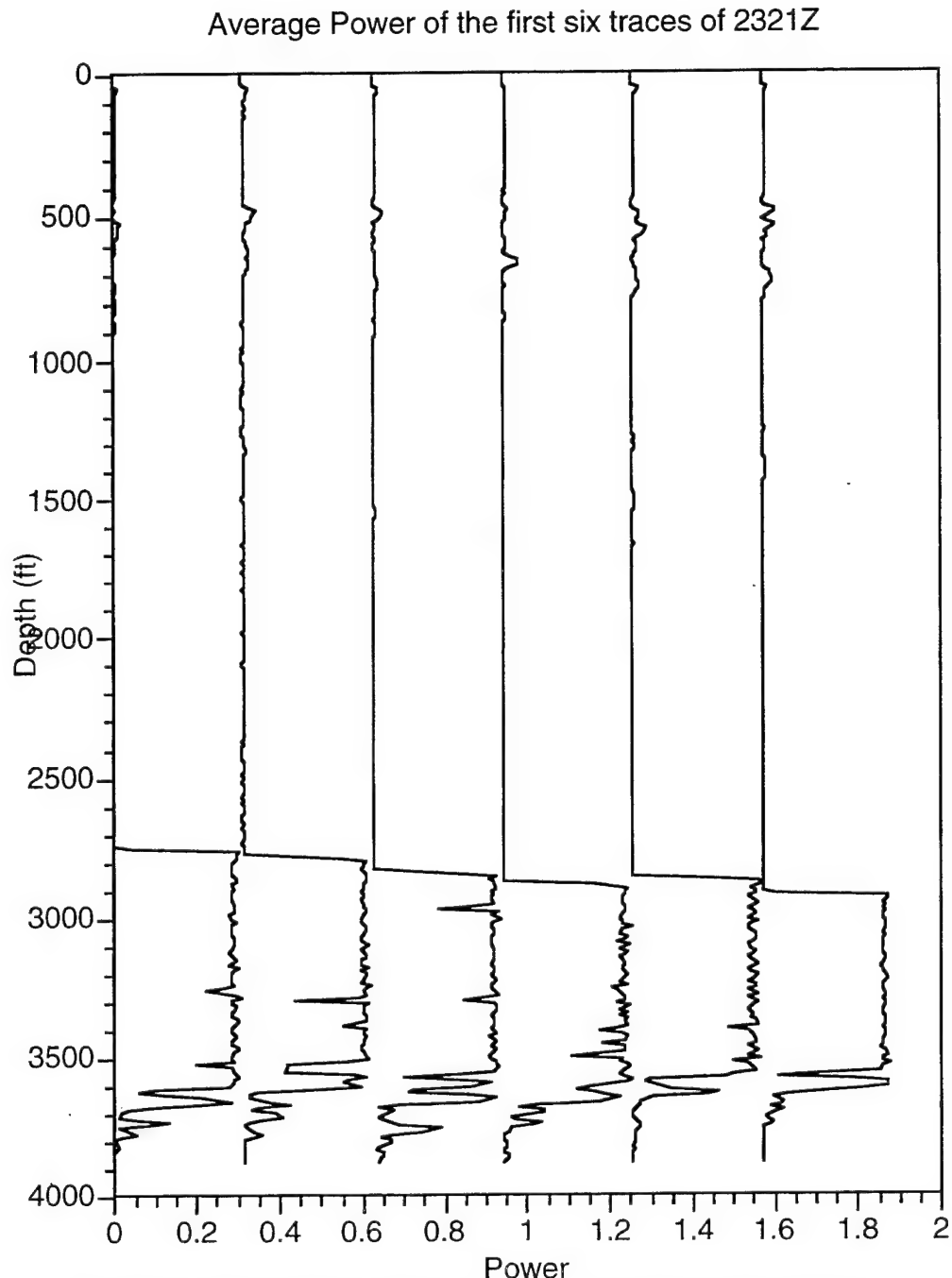


Figure 13. An Example of Decimated Data from Six Acoustic Pings.

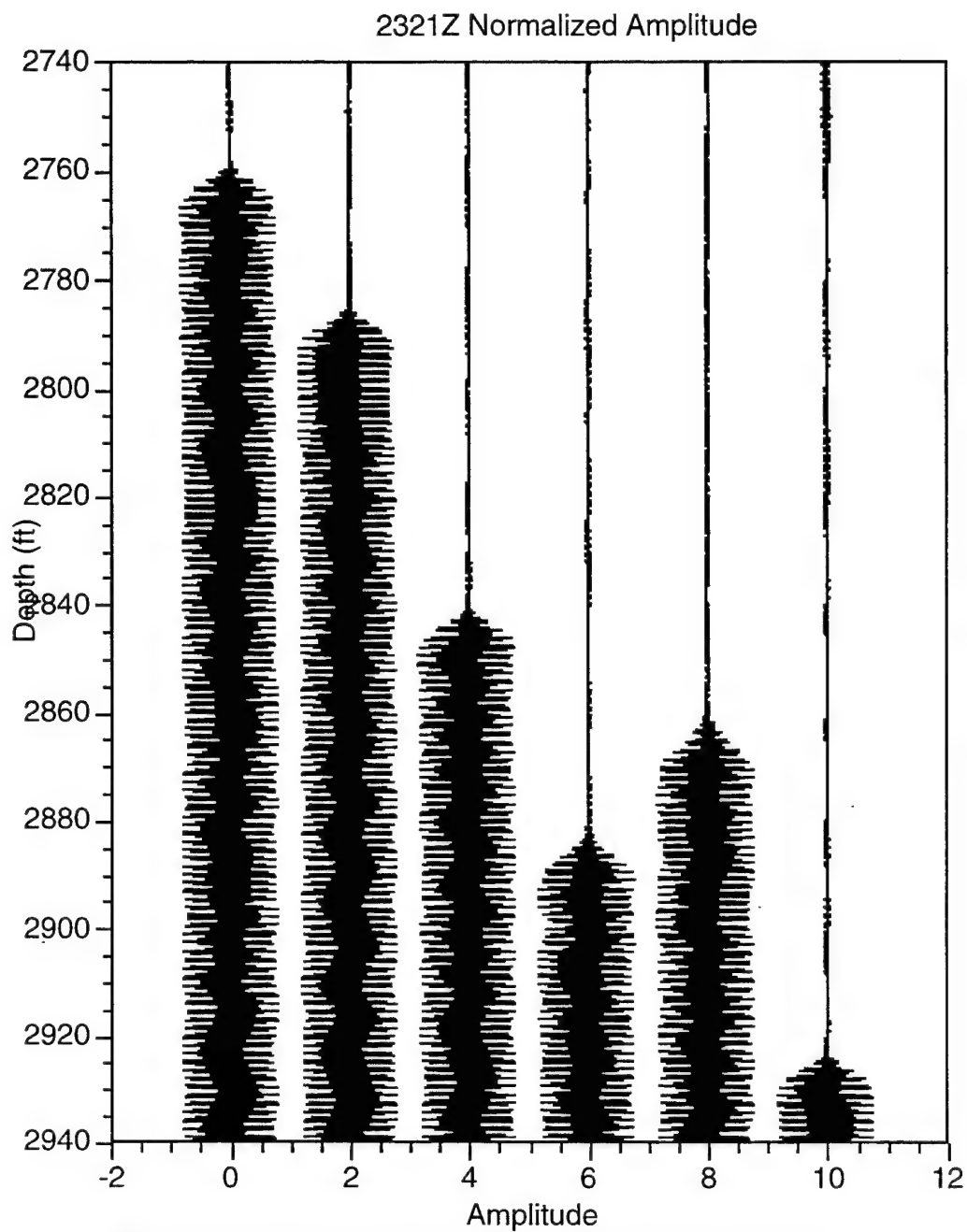


Figure 14. An Example of Six Pings without any Decimation.

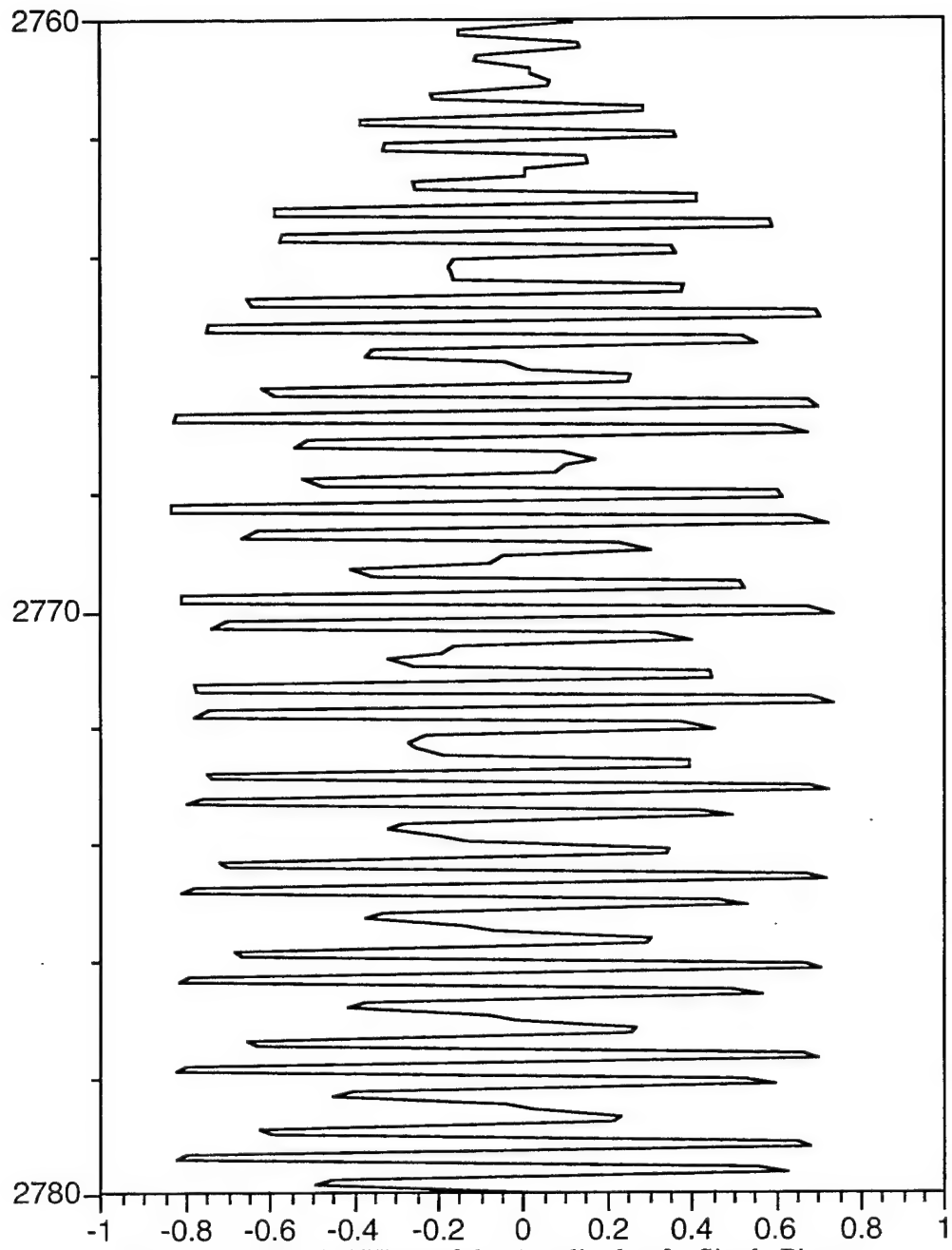


Figure 15. Detailed View of the Amplitude of a Single Ping.

2321Z Trace 000
Every Point

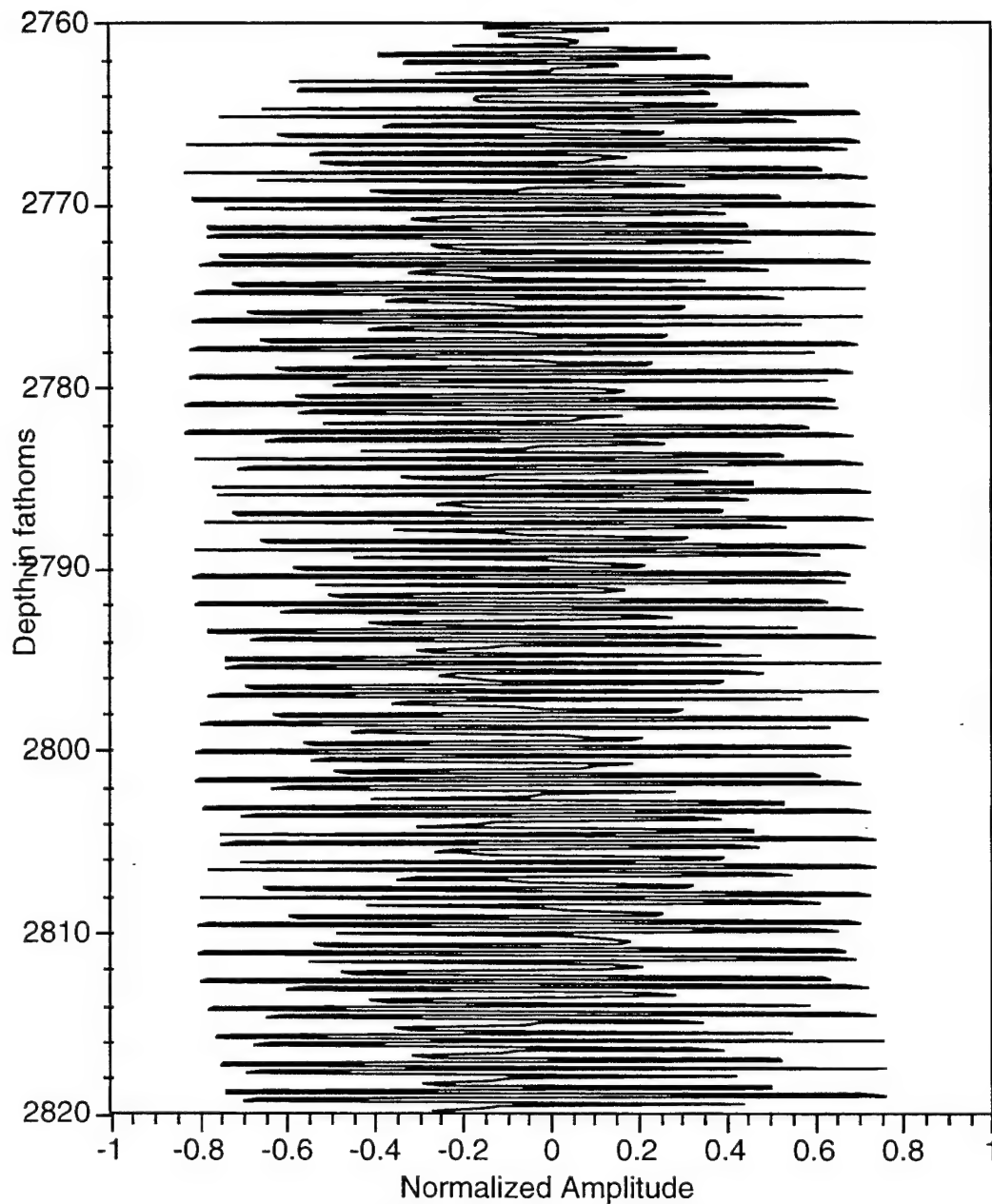


Figure 16. Detailed View of the Amplitude of a Single Ping.

AN/UQN-4 data @ 2321Z, Run 6

Sample Rate= 22050

Every Point Shown

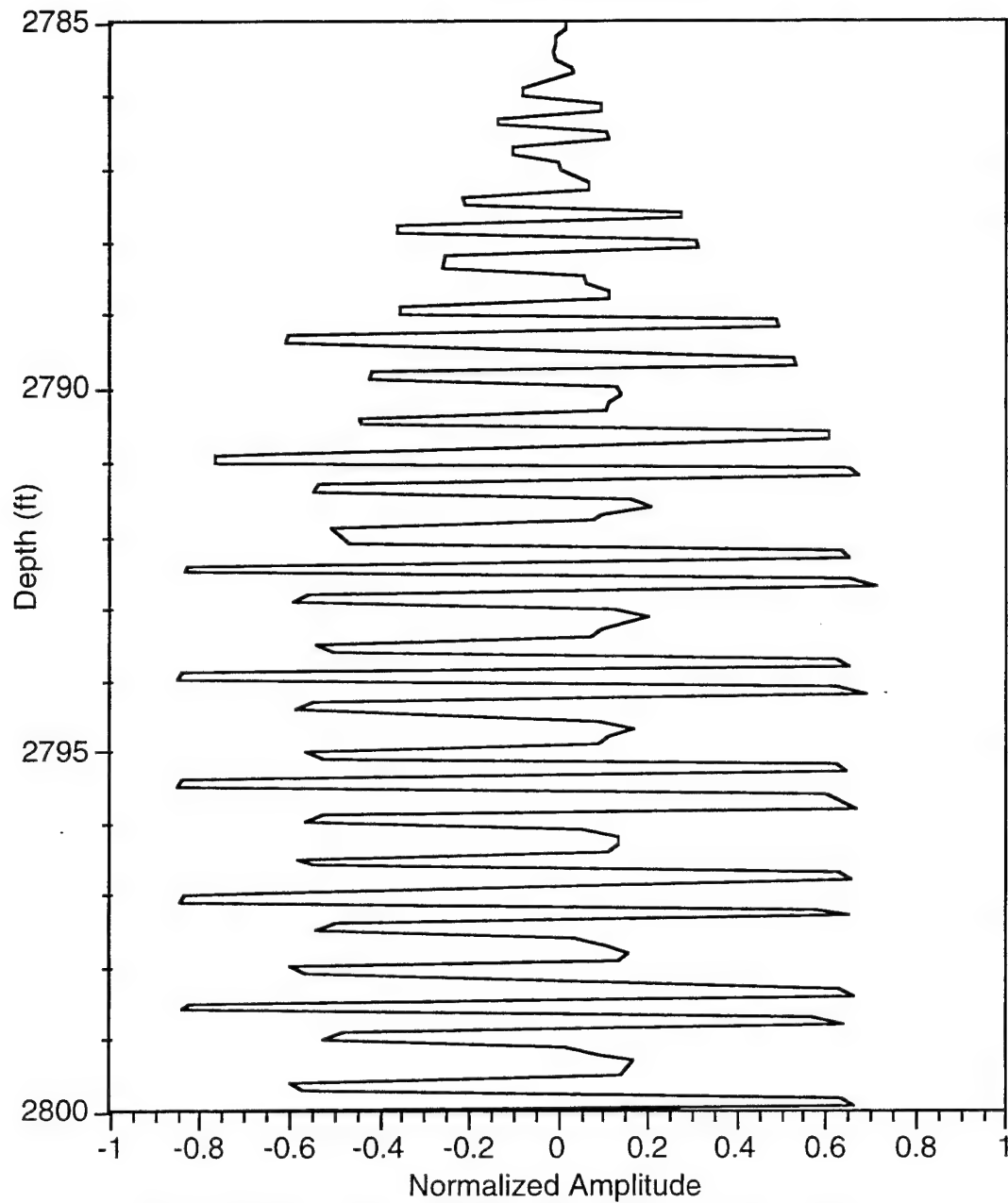


Figure 17. Time Expanded First Part of Pulse in Figure 16.

2321Z #0001

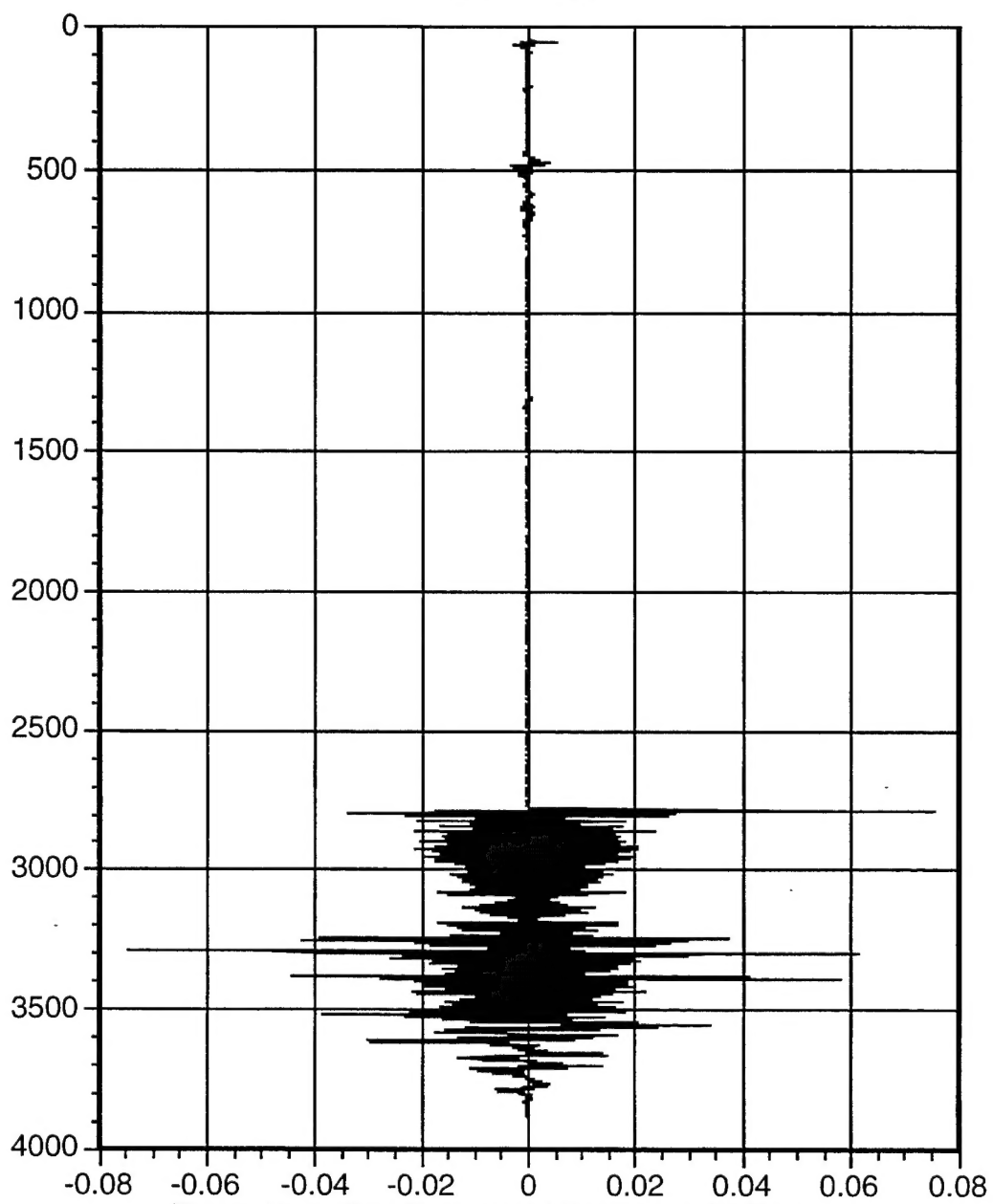


Figure 18. A Time Compressed Depth Sounder Trace.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The objective of this task was to demonstrate that the AN/UYQ-25B(V) (SIMAS) could obtain current in-situ bathymetric and geoacoustic information from the AN/UQN-4A Sonar Sounding Set (depth sounder) in the littoral regions where vessels equipped with SIMAS systems will operate. As the first step, a sea test was planned and conducted to collect acoustic time series and digital depth output data from the depth sounder for recording and transmission to the SIMAS system on-board the USS Curtis Wilbur (DDG-54). It was demonstrated that the digital depth output of the depth sounder could be acquired with little effort at a 30 second time interval instead of the present 5 minute time interval provided by ASWCS through the present data link. In addition, if the present depth sounder is modified to inhibit the writing to chart paper, then the sonar transmission pulse rate (ping rate) could be increased to provide shorter time intervals between depth samples to easily less than 3 seconds. A ship traveling at 20 knots (approximately 33 ft/sec) would travel 10134 ft in 5 minutes, 1013 ft in 30 seconds and 101 ft in 3 seconds which demonstrates the desirability of SIMAS obtaining the depth data directly from the depth sounder and the desirability improving the AN/UQN-4A to achieve higher ping rates for time intervals less than 3 seconds.

The data clearly demonstrated the presence of geoacoustic information in the depth sounder acoustic return from the stratigraphy below the ship but the limited bandwidth makes the extraction of this information complicated. Extraction of the geoacoustic information from these limited bandwidth traces would require successive regression to separate the time horizons and amplitudes of the reflections from each layer in the stratigraphic cross-section below the ship. This is computationally inefficient and is easily remedied by increasing the bandwidth of the transmitted signal, either through spread spectrum techniques, or through the use of shorter pings at a higher frequency. This would require augmenting the present AN/UQN-4A by changing its signal processing methodology, or alternatively, sharing the present transducer with an additional transmitter, receiver, and signal processing hardware.

It is recommended that the AN/UQN-4 be interfaced to SIMAS II to provide the required bathymetric data. It is further recommended that the bandwidth of the transmitted signal be increased to permit cost-effective extraction of sea floor geoacoustic parameters.

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